

Efficient Tm:Fiber Pumped Solid-State Ho:YLF 2- μ m Laser for Remote Sensing Applications

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Abstract: An efficient 19 W, TEM₀₀ mode, Ho:YLF laser pumped by continuous wave Tm:fiber laser has been demonstrated at the room temperature. The slope efficiency and optical-to-optical efficiency are 65% and 55%, respectively.

OCIS codes: (140.3580) Lasers, solid-state; (140.3510) Lasers, fiber.

1. Introduction

Ho lasers operating around the wavelength of 2 μ m have many specific applications in atmospheric surveillance (such as wind/CO₂ measurement) due to high water absorption, strong aerosol scattering and eye-safety [1]. Diode pumped Ho:Tm co-doped laser crystal is the most common way to generate high energy 2 μ m laser [2], but upper laser state absorption, Tm and Ho energy sharing, concentration quenching, as well as large heat loading limits the efficiency. One way to eliminate or alleviate these effects is to make Ho and Tm in separate crystals. Experimentally, higher efficiency has been obtained from a diode pumped Tm:YAG laser pumped Ho:YLF laser [3]. In recent years, great advancement have been made in fiber laser technology, and Tm:fiber lasers with an output of > 100W are commercially available. Compared to a Tm:solid-state laser, the Tm:fiber laser has a higher efficiency (long interaction length and energy trap in the waveguide) and easier heat removal (long length and small diameter). A higher wall-plug efficiency was demonstrated when a Tm:fiber laser replaces the Tm:solid-state laser as the pump source for Ho:YLF laser [4,5].

In this paper, we report a Tm:fiber laser pumped Ho:YLF laser with highly efficient continuous-wave operation at room temperature. The slope and optical-to-optical efficiencies are 65% and 55%, respectively.

2. Laser configuration

The designed Tm:fiber laser pumped Ho:YLF laser has a zigzag configuration and is as shown in Figure 1. The maximum output power of the Tm:fiber pump laser is 40W in random polarization. The radius of its output beam is about 5mm and the peak wavelength is 1.941 μ m. It is off the absorption peak of Ho:YLF crystal by 2 nm, but there is still strong absorption at the wavelength. This pump beam is focused on the Ho:YLF crystal by a concave mirror with one meter radius of curvature. The waist of the focused beam is 0.46mm at $1/e^2$. The full divergence angle of the focused beam is about 2.6 mrad. For mode matching, the pump and laser beams have the same confocal parameters. Ho:YLF lasers present low threshold and high efficiency when the pump polarization is at π orientation due to the birefringent nature of the crystal. By appropriate feedback from the back mirror of the laser, the polarization of Tm:fiber laser output is changed from random polarization to linear polarization. This modification creates >90% pump power (34.4W) injected to laser crystal at π -polarization. The Ho:YLF crystal is 1% Ho doped concentration and 5mmx5mmx30mm in dimension. It is cooled by refrigerated water at 10°C. The laser cavity consists of two flat highly reflected mirrors, one concave (the radius of curvature is 0.5m) and one flat coupler (R=40%). The total laser cavity length is 1.3m.

3. Laser performance

Based on quasi-three level modeling, pump absorption and saturation depend on laser intensity. On the other hand, laser amplification and saturation depend on pump intensity in the crystal. Small pump volume is desirable for obtaining high efficiency, but possible crystal damage must be considered for the reduced pump beam. In our experiment, the pump beam size on the front of Ho:YLF crystal is 0.512mm in radius. The experimental result is depicted in Fig.2. The laser slope efficiency is 64.72% with a threshold of 5.36 W. The maximum output power is 19W in TEM₀₀ mode at 2.051 μ m when the π -polarization pump power is 34.4 W. The corresponding optical-to-optical efficiency is 55.23%.

4. Summary

We have designed a Tm: fiber laser end-pumped Ho:YLF laser considering thermal lens effect in the Ho:YLF crystal. This design has the following characteristics: mode matching between pump and laser beams, small pump volume, and controlling pump beam from random polarization to linear polarization by supplying linear polarization feedback to the Tm: fiber laser. The continuous-wave TEM₀₀ mode laser power at 2.05 μm can reach 19 W at room temperature. The corresponding slope efficiency and the optical to optical efficiency are 65% and 55%, respectively.

5. References

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